

EXCLUSIVE CHANNELS IN PHOTON-PHOTON COLLISIONS AT LEP

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The study of exclusive channels in photon-photon collisions at e^+e^- colliders allows to investigate the structure and the properties of hadrons in a very clean experimental environment. A concise review of the most recent results obtained at LEP is presented.

1 Introduction

Photon-photon collisions at e^+e^- colliders are studied using the two-photon fusion process $e^+e^- \rightarrow e^+e^-X$. In this reaction the outgoing electron and positron are usually scattered at very small angles and are not detected. The two photons are quasi real and the final state X must be neutral and unflavoured with $C=1$ and $J \neq 1$. The study of exclusive channels is characterized by a full reconstruction of the final state X .

The cross section for this process is given by the convolution of the QED calculable luminosity function \mathcal{L} , giving the flux of the virtual photons, with the two-photon cross section $\sigma(\gamma\gamma \rightarrow X)$ which is sensitive to the quark structure of the final state X .

The study of baryon-antibaryon pair production allows to probe the quark structure of the baryons which can be modeled in terms of three-quark¹ and quark-diquark bound states². Since the electric charge of the constituent partons is different in the two models, the predictions for the cross section differ of more than one order of magnitude.

If the final state is a single resonance R , $\sigma(\gamma\gamma \rightarrow R)$ is expressed by a Breit-Wigner function proportional to the two-photon width $\Gamma_{\gamma\gamma}(R)$ which contains all the physical information of the process. Below the charmonium threshold, the measurement of the two-photon width allows to study QCD in the non-perturbative region and gives fundamental information on the nature of glueball candidates. Since gluons do not couple directly to photons, the two photon width of a glueball is expected to be very small. Above the charmonium threshold, the measurement of the two photon width of charmonia and bottomonia allows to test perturbative QCD predictions.

If one of the two photons is highly virtual, the spin of the final state is allowed to be one. The virtuality is taken into account in the cross section by multiplying the Breit-Wigner function by a VDM pole transition form factor which can be calculated using phenomenological models^{3,4}.

A more exhaustive review of the results obtained in this field in the last few years can be found elsewhere⁵.

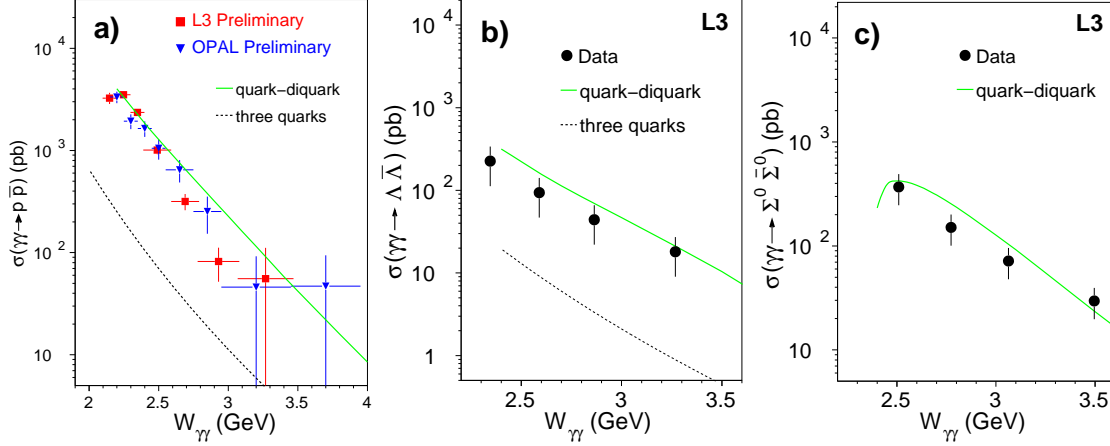


Figure 1: The cross section for $p\bar{p}$ (a), $\Lambda\bar{\Lambda}$ (b) and $\Sigma^0\bar{\Sigma}^0$ (c) exclusive production.

2 Baryon-antibaryon production

The cross section for $p\bar{p}$ exclusive production is measured by OPAL⁶ and L3⁷ as a function of the two-photon effective mass $W_{\gamma\gamma}$, using 249 pb^{-1} and 610 pb^{-1} of data collected at $\sqrt{s} = 183\text{--}189 \text{ GeV}$ and at $\sqrt{s} = 183\text{--}209 \text{ GeV}$, respectively. Good agreement is found between the two measurements and the predictions of the quark-diquark model², as presented in fig. 1(a). The predictions of the three-quark model¹ are found to be inconsistent with the data.

The study of the $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$ exclusive production is performed by L3⁸. In particular, the $\Sigma^0\bar{\Sigma}^0$ exclusive production is studied for the first time. Using 844 pb^{-1} of data collected at $\sqrt{s} = 91\text{--}208 \text{ GeV}$, 19 $\Lambda\bar{\Lambda}$ and 14 $\Sigma^0\bar{\Sigma}^0$ candidate events are selected. The two measurements of the cross section as a function of the two-photon effective mass $W_{\gamma\gamma}$ are shown in fig. 1(b) and fig. 1(c). Good agreement is again found with the predictions of the quark-diquark model. Data are inconsistent with the three-quark model predictions.

3 Formation of light resonances

The $K_S^0 K_S^0$ final state is studied by L3⁹ using 588 pb^{-1} of data collected at $\sqrt{s} = 91\text{--}202 \text{ GeV}$. The $K_S^0 K_S^0$ mass spectrum is found to be characterized by three resonant signals over a small background, as presented in fig. 2(left). The peak in the $1100\text{--}1400 \text{ MeV}$ mass region is due to the destructive $f_2(1270)\text{--}a_2(1320)$ interference. The spectrum is dominated by the formation of the $f_2'(1525)$ tensor meson in helicity 2 state for which $\Gamma_{\gamma\gamma}(f_2'(1525)) \times \text{BR}(f_2'(1525) \rightarrow K\bar{K}) = 76 \pm 6 \pm 11 \text{ eV}$. The signal at 1750 MeV mass is found to be dominated by the 2^{++} , helicity 2 wave. This is interpreted as the formation of a radially excited tensor meson for which $\Gamma_{\gamma\gamma}(f_2(1750)) \times \text{BR}(f_2(1750) \rightarrow K\bar{K}) = 49 \pm 11 \pm 13 \text{ eV}$. A fraction of $24 \pm 16\%$ of the 0^{++} wave is also found. No signal for the $\xi(2230)$ tensor glueball candidate is observed. The upper limit $\Gamma_{\gamma\gamma}(\xi(2230)) \times \text{BR}(\xi(2230) \rightarrow K_S^0 K_S^0) < 1.4 \text{ eV}$ at 95% C.L. is obtained.

The formation of spin one states in two-photon collisions is possible if one of the two photons is virtual. The virtuality Q^2 is evaluated experimentally by measuring the total transverse momentum imbalance P_t of the decay products of the resonant state. Monte Carlo studies show that $Q^2 \simeq P_t^2$. The $\eta\pi^+\pi^-$ final state as a function of Q^2 is studied by L3¹⁰. The four mass spectra presented in fig. 2(right) show the evolution of the formation of the $f_1(1285)$ as a function of Q^2 . The signal reduces to zero at low Q^2 , due to the Landau-Yang theorem which forbids the formation of spin-one states by two real photons. From these mass spectra the cross section is measured as a function of Q^2 and is compared to the theoretical predictions based on different

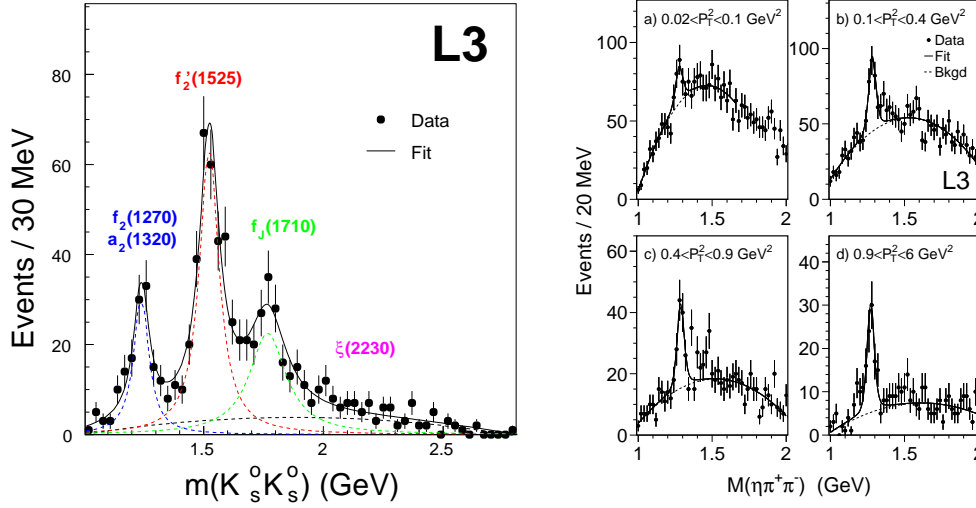


Figure 2: The $K_S^0 K_S^0$ mass spectrum (left) and the $\eta\pi^+\pi^-$ mass spectrum as a function of Q^2 (right).

parametrizations of the transition from factor. The calculation by Cahn⁴ leads to a confidence level below 10^{-9} and is therefore found incompatible with the data. The parametrization by Schuler et al.³ leads to a confidence level of 2% if the mass of the pole is fixed to the mass of the $f_1(1285)$. A confidence level of 91% is found leaving the parameters Λ and $\tilde{\Gamma}_{\gamma\gamma}$ free in the fit. From this fit, the values $\Lambda = 1.04 \pm 0.06 \pm 0.05 \text{ GeV}$ and $\tilde{\Gamma}_{\gamma\gamma} = 3.5 \pm 0.6 \pm 0.5 \text{ keV}$ are obtained.

4 Search for the η_b

The η_b meson is the $b\bar{b}$ ground state and its experimental observation is still missing. According to theoretical perturbative QCD and lattice QCD predictions, the difference $m(\Upsilon) - m(\eta_b)$ is in the range from 34 to 141 MeV and the two-photon width of the η_b is between 500 and 570 MeV. The branching ratios into four and six charged particles are estimated to be 2.7% and 3.3% respectively. The search for the η_b represents therefore an exciting challenge and a very important test for QCD.

Due to the high mass of this state, the background from other two-photon processes is very small and high energy LEP data above the W pair production threshold represent a very good environment to search for this meson. According to the predictions, about six η_b mesons are expected to be produced per decay channel and per experiment. The number of observed events will be sensitively reduced due to acceptance and efficiency effects.

A search for the η_b meson is performed by ALEPH¹¹ using an integrated luminosity of 699 pb^{-1} collected at $\sqrt{s} = 181\text{-}209 \text{ GeV}$. No candidates are found in the four charged particle decay mode. With an expected background of 0.30 ± 0.25 events, the upper limit $\Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}(4 \text{ charged}) < 48 \text{ eV}$ at 95% C.L. is derived. One candidate is found in the six charged particle decay mode. This candidate is shown in fig. 3 and is found to have a mass of $9.30 \pm 0.02 \pm 0.02 \text{ GeV}$, very close to theoretical predictions. It is important to remark the clear presence of a K_S^0 and a K^- strange mesons in the event. Since the direct formation of s quarks in two-photon collisions is suppressed, this event is very probably due to the formation of a high mass resonant state. With an expected background of 0.70 ± 0.34 events, the upper limit $\Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}(6 \text{ charged}) < 132 \text{ eV}$ at 95% C.L. is derived.

In a preliminary study of the formation of the η_b meson, L3¹² reports the observation of some candidates in the mass region of interest. Using a luminosity of 610 pb^{-1} collected at $\sqrt{s} = 183\text{-}209 \text{ GeV}$, 1 candidate in the four charged, 1 candidate in the six charged and 2 candidates

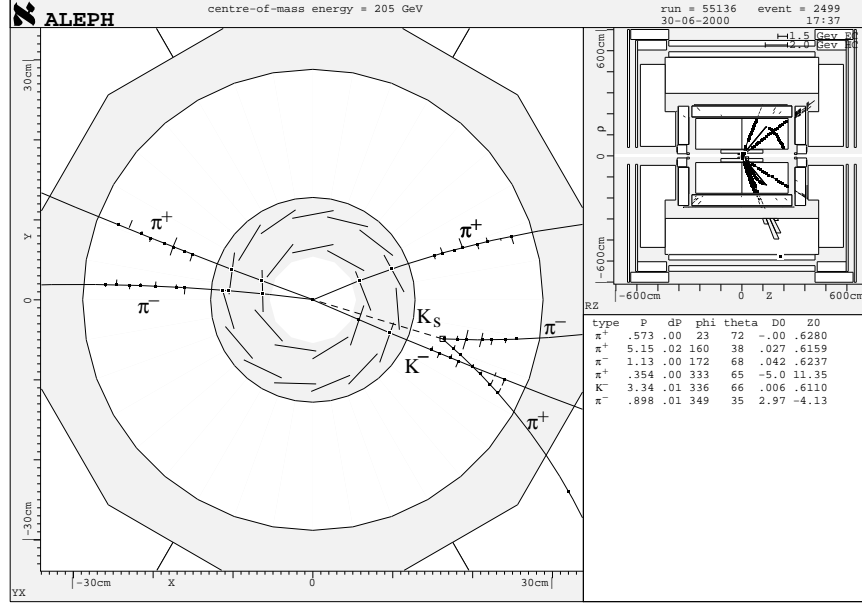


Figure 3: The $\eta_b \rightarrow 6$ charged particles candidate event by ALEPH.

in the two charged particle and one π^0 final states are found.

These results indicate a possible formation of the η_b meson in photon-photon fusion. Due to the very limited statistics, a combination of the results of all the four LEP collaborations will be mandatory to have the possibility to claim the observation of this state.

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